Organization: The Ohio State University

Title: Bio-Fluid Transport Models Through Nano- And Micro-Fluidic Components

MTO **Simbiosys**

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Project Goals

This project aims to develop the scientific foundations of bio-fluid mass transport through micrometer- and nanometer-sized conduits through a combination of experimental investigation, analysis, and computer modeling. The ultimate goal is to develop a unified scale-dependent theory of the mass transport properties of biological fluids based on experimentally determined constitutive relationships, for application to computer modeling of micro- and nano-fluidic systems for bio-fluids.

Technical Approach

- Derive an analytical, scale-dependent flow model for nanochannel fluid transport which accounts for EDL and surface effects for both pressure-driven and electrokinetic flow, and use for numerical simulations of flow through the experimental geometries.
- Fabricate nanochannels in silicon using two basic designs for separate measurements of mass flow and fluid velocity. Initial nanochannels will have sizes of 10, 20, 30, 50, and 100 nm.
- Fabricate nanochannells in the four main polymers of interest: silicone (PDMS), acrylic (PMMA), Teflon (PTFE), and polystyrene (PS).
- Deposit silane monolayers using vapor phase deposition for the control of surface chemistry within nanochannels
- Measure empirical models of fluid flow in the nanochannels and compare to theoretical models
- Derive models of linear and globular molecule transport through nanochannels using the models derived for homogeneous fluid flow
- Compare the derived models for molecular flow with molecular flow experiments. Compare biological activity of the biomolecules pre- and post-flow to determine effect on biochemical signal for analytical chemistry.

Recent Accomplishments

- Completed series of nanochannels with 10, 20, 30, 50 and 100 nm channels
- Completed analytical/computational model of electroosmotic flow that matches experimental data and gives standard electroosmotic flow in microchannels with multivalent ion effects
- Characterizatized pressure-driven and electroosmotic flow through 20nm chip, compared with theory
- Fabricated nanochannels in PDMS and methacrylates
- Performed initial characterization of flow in polymer nanochannels
- Deposited uniform monolayers of three types of silanes across 4" silicon wafer and within nanochannel chip, characterized with contact angle, ellipsometry, and XPS

Six-Month Milestones

- Measure electroosmotic and pressure-driven flow of saline through nanochannels of various sizes and with different surface chemistries; produce empirical model based on measurements
- Use analytical model of flow to determine effect of transport on globular proteins and linear DNA
- Experimentally test effect of flow through nanochannels on ferritin for confirmation of model
- Use CFD-ACE+ to completely model 2-dimensional flow within physical geometry fabricated, work with CFDRC to implement analytical model into code
- Fabricate volumetric flow test chip in PDMS; modify surface chemistry with silane monolayer and test time-dependence of surface properties

Team Member Organizations

The Cleveland Clinic Foundation

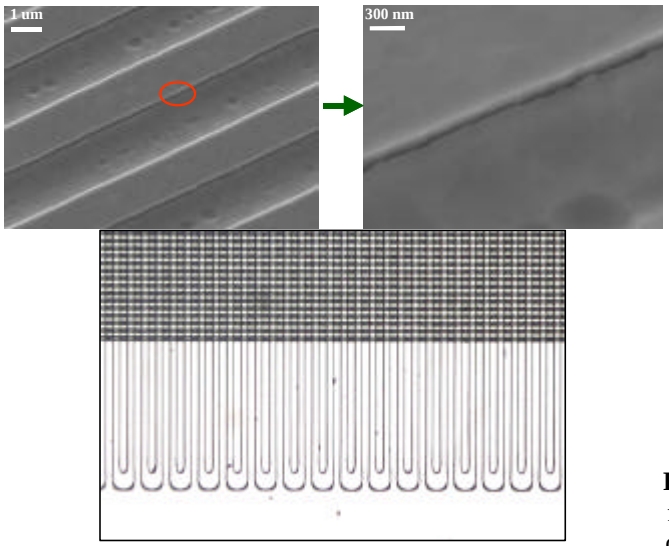

Figure 1: Electron (top) and optical (bottom) micrographs of silicon nanochannels

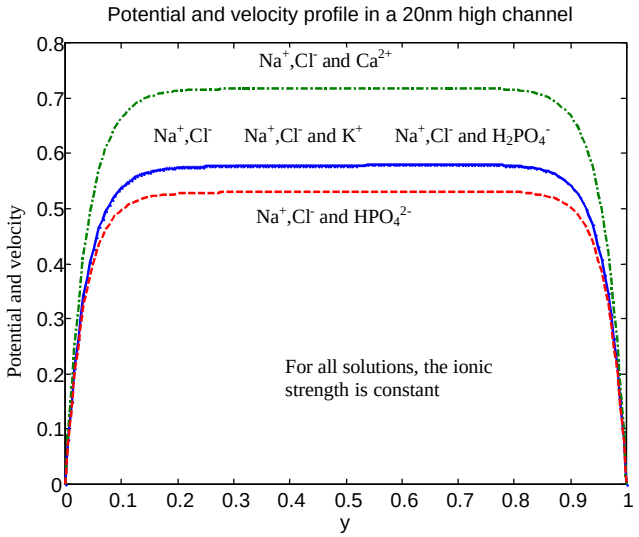

Figure 2: Potential and velocity profile across a 20nm channel for different saline compositions with the same ionic strength, demonstrating the effect of multivalent ions on electroosmotic velocity

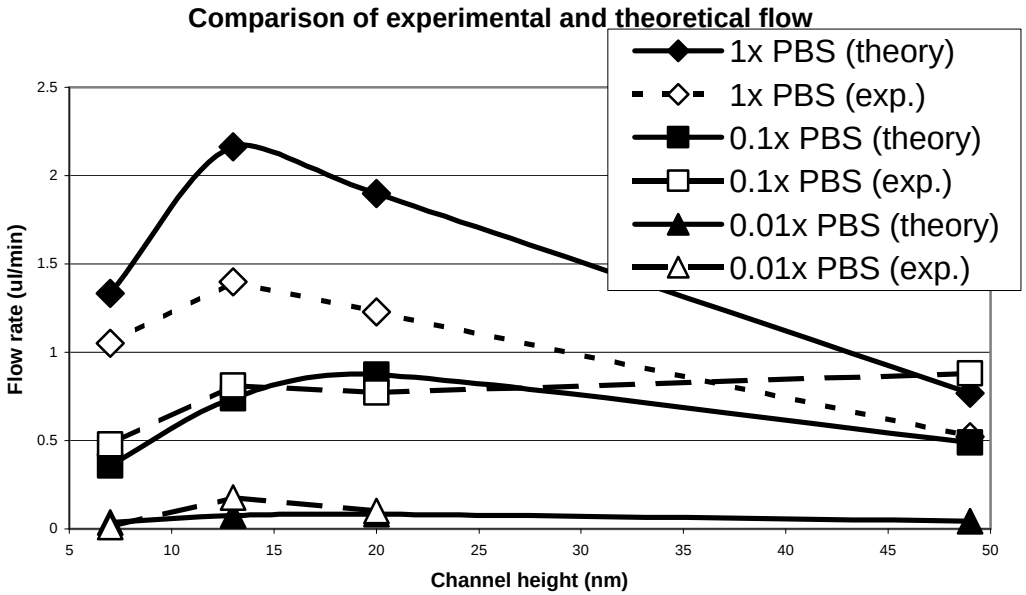

Figure 3: Electroosmotic flow measurements compared to analytical theory